Future Needs in Climate Modeling: Aerosol-Cloud Interactions

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- emergent quantities
  - precipitation
  - radiative fluxes
  - others

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- observational statistical quantification attempts not enough!
  - disentangling microphysics and dynamics too complex
  - easily misleading (cause, effect?)
  - ship tracks only in shallow marine Sc (mesoscale response?)
  - models generally *required* for quantification
  - and for climate prediction (parameterization development)

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- setting the stage
  - seasonally ice-free Arctic, Greenland melting, sea level rise
  - tools for comparing costs (sea walls versus reactors)
  - aerosol indirect effect bar charts lose significance, magnitude?
  - aerosol effects = what prevented early detection?
  - precipitation and regional climate prediction gain importance
  - long-term goals: understand cloud physics, make GCMs work

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- what does this mean?
  - we need high vertical resolution to lowest altitudes
  - we need high horizontal resolution
  - "high resolution" = order 10-100 m
  - we need to aim for aerosol *number size distribution*
  - we need ground-based data (sub-cloud aerosols, dynamics)
  - we'd like to know LWP, N_d, and precipitation to 0.1 mm/d

ACE Mission

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- some general issues
  - radar resolution crucial (orbit height)
  - single beam sufficient for wide homogeneous clouds
  - but scanning radar would boost statistics enormously
  - multiple-beam lidar offers similar advantages
  - single beam can miss horizontal structure
  - how will *dry* aerosol NSD be cornered?

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- "simulator" studies (let's get together)
  - German HALO aircraft instruments
  - DOE ARM ground-based radar facility
  - ESA EarthCARE mission

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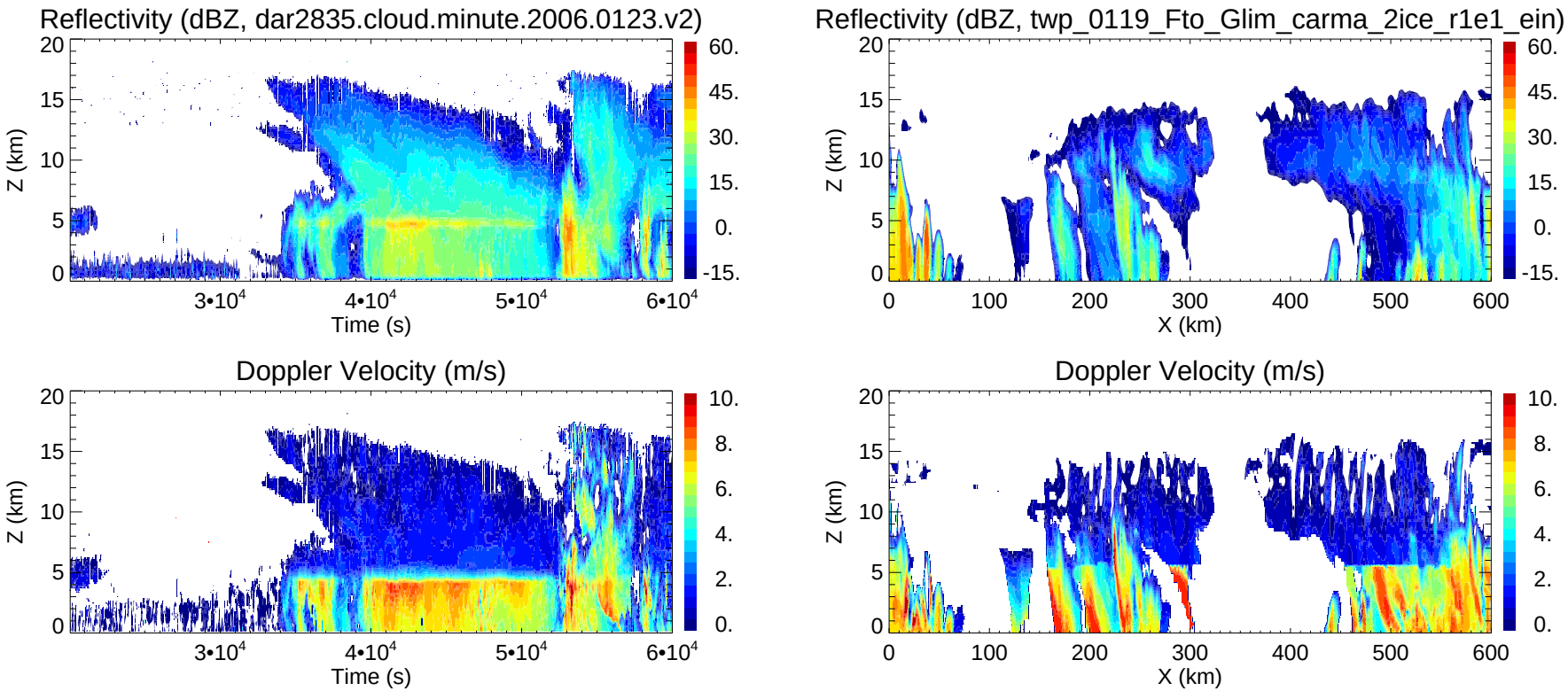
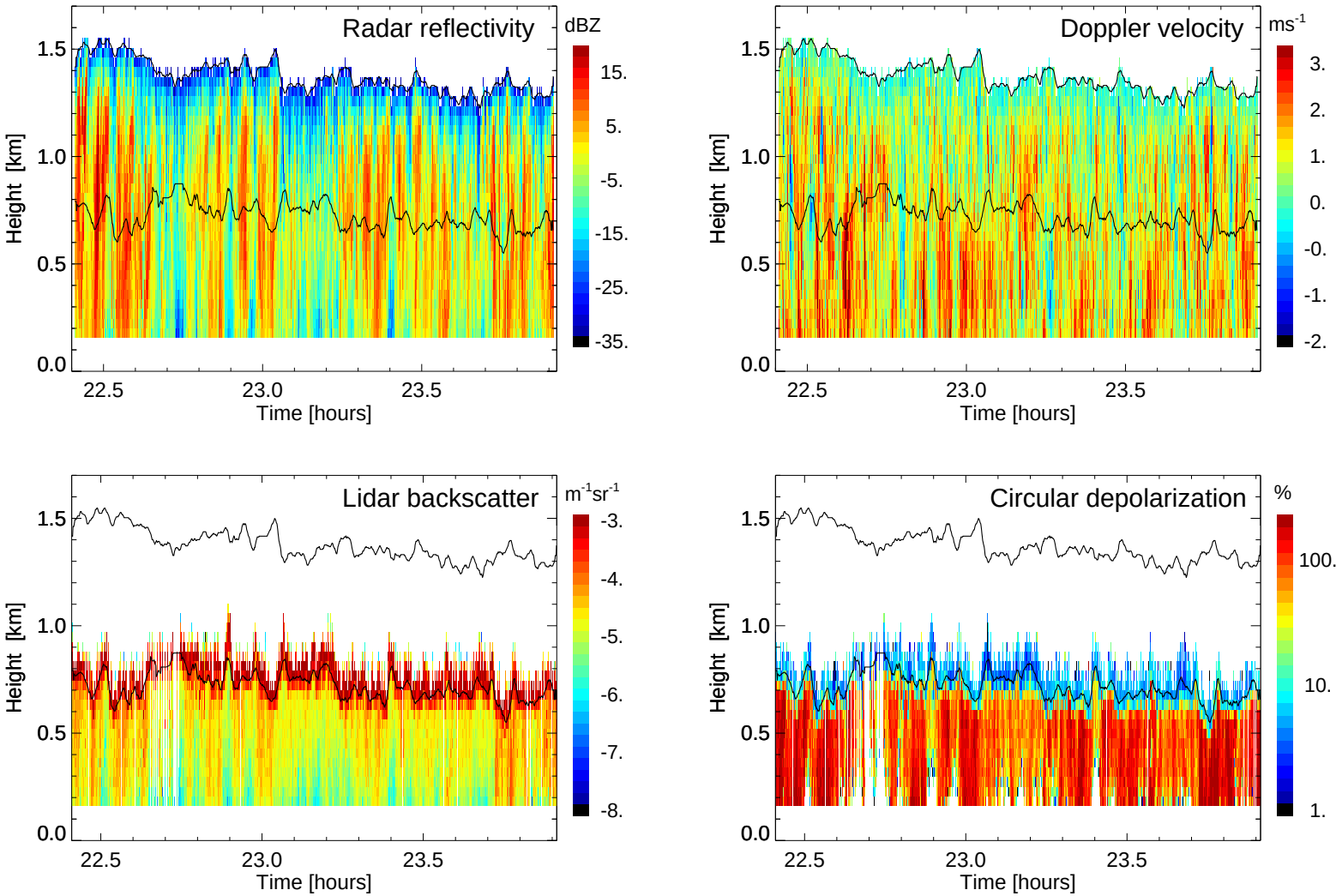
- not a cure-all
  - still need clear scientific questions
  - still face trade-offs
- part of the future (and ACE?)
  - doesn't need to be expensive or time-consuming
  - basic technology in hand (e.g., Quickbeam)
  - same technology useful for later science

2.8 GHz Radar (S-Band) Reflectivity + Doppler Velocity



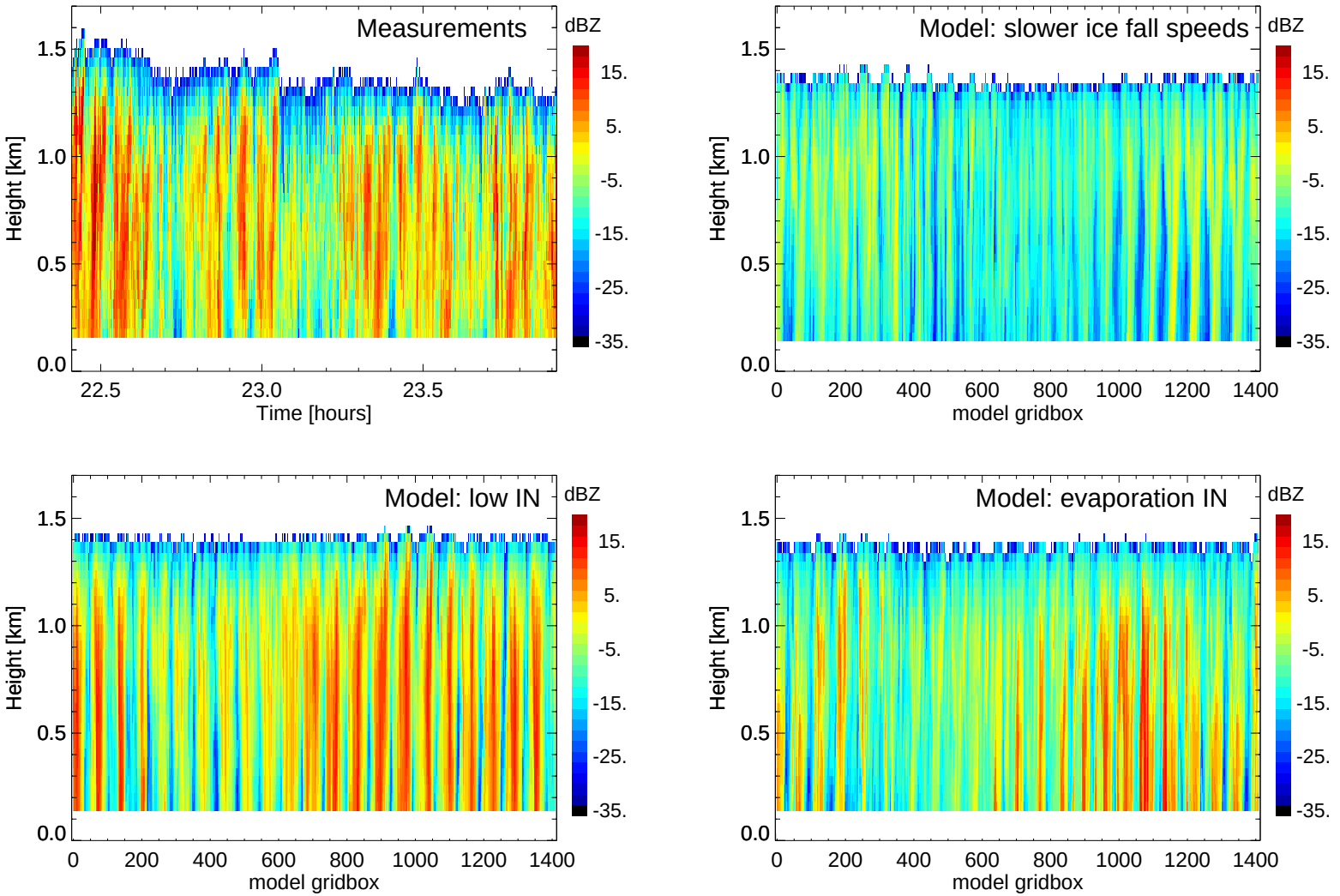
Source: *Data courtesy Christopher Williams (NOAA), DOE ARM data archive*

94-GHz Radar (MMCR) and Lidar (HSRL)



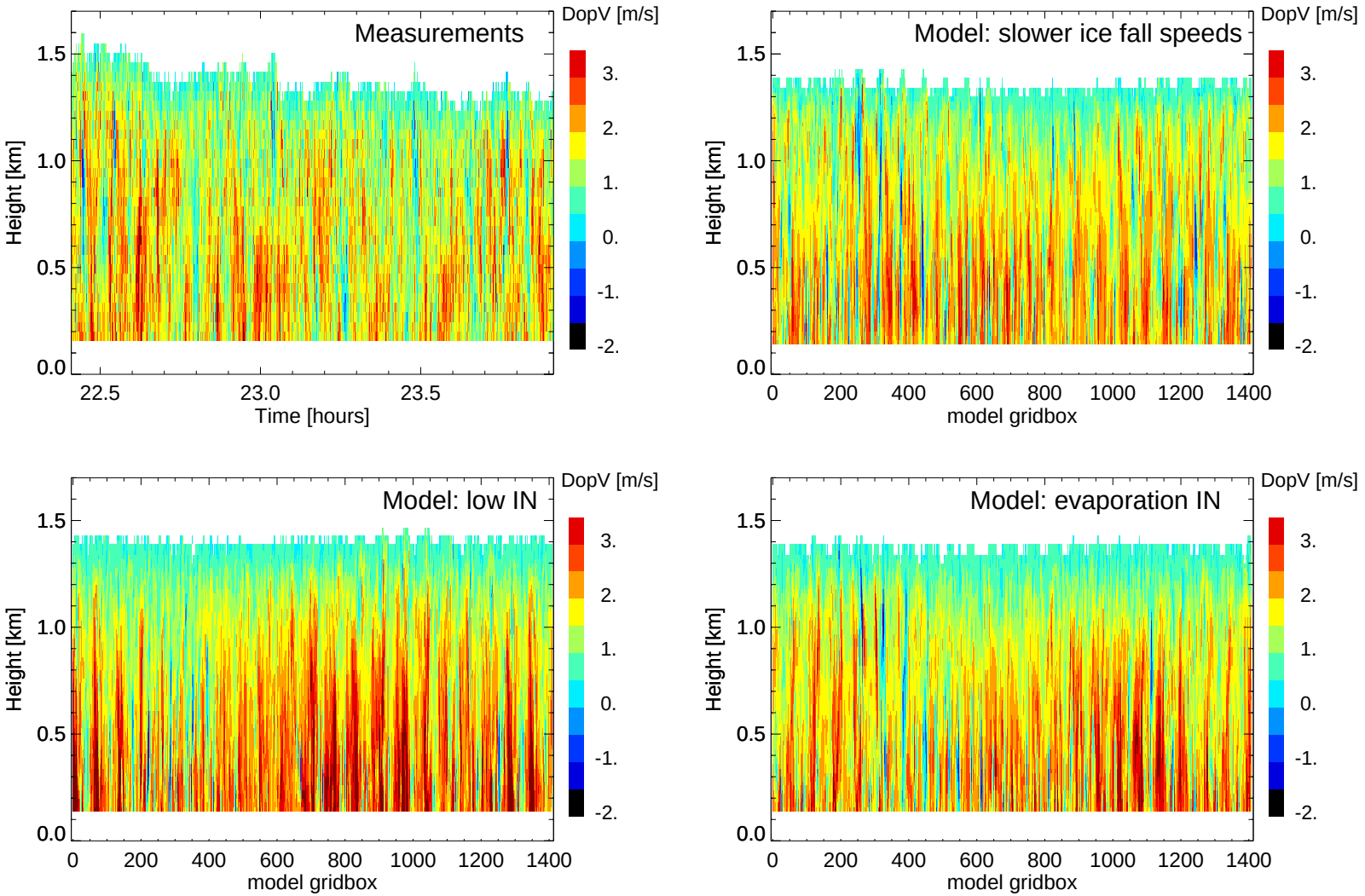
Source: *Data courtesy DOE ARM and Ed Eloranta / U. Wisc.*

94-GHz Radar Reflectivity



Source: *QuickBeam (http://reef.atmos.colostate.edu/haynes/radarsim/), Bastiaan van Diedenhoven / NASA GISS*

94-GHz Radar Doppler Velocity



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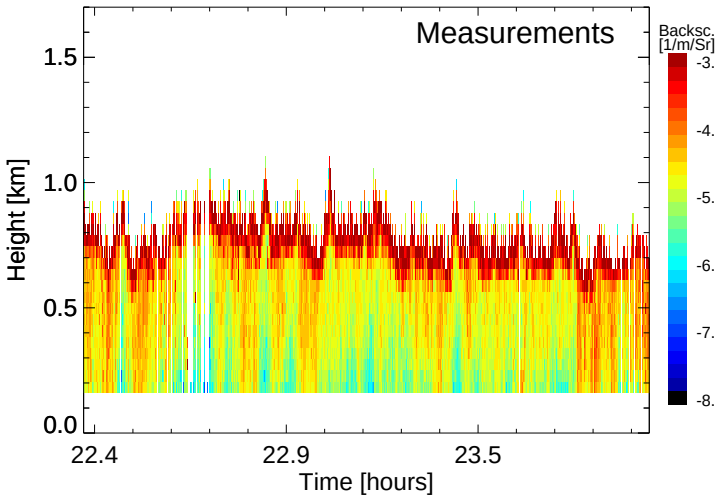
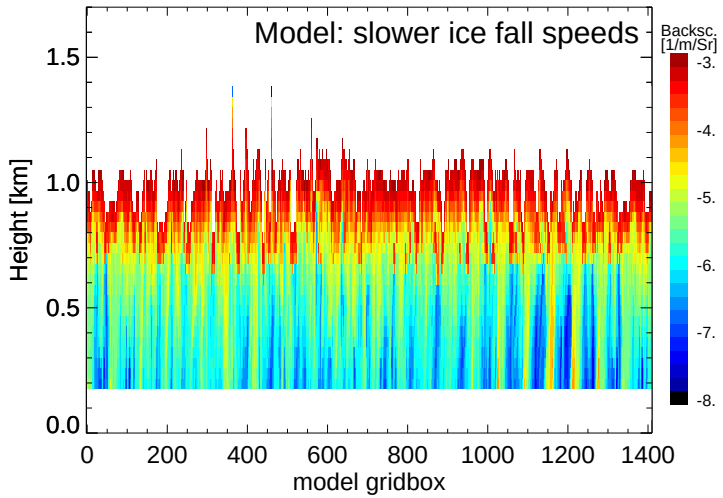
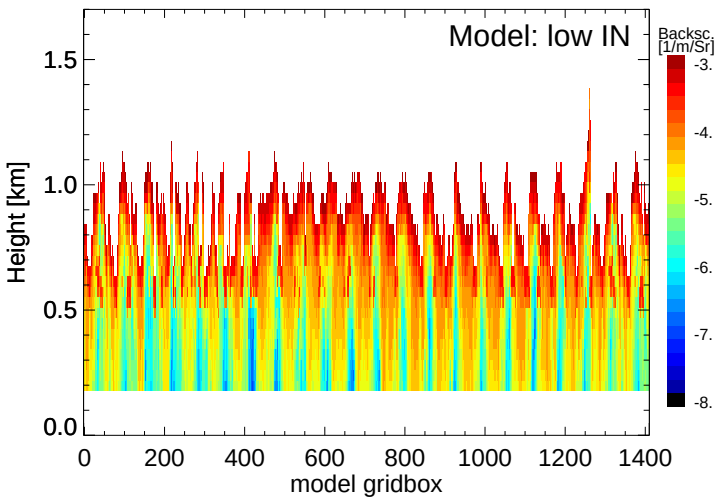
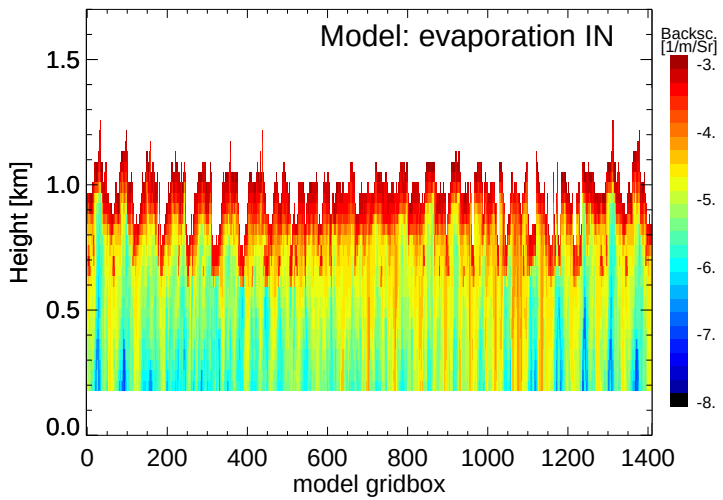
Lidar Backscatter Cross-Section









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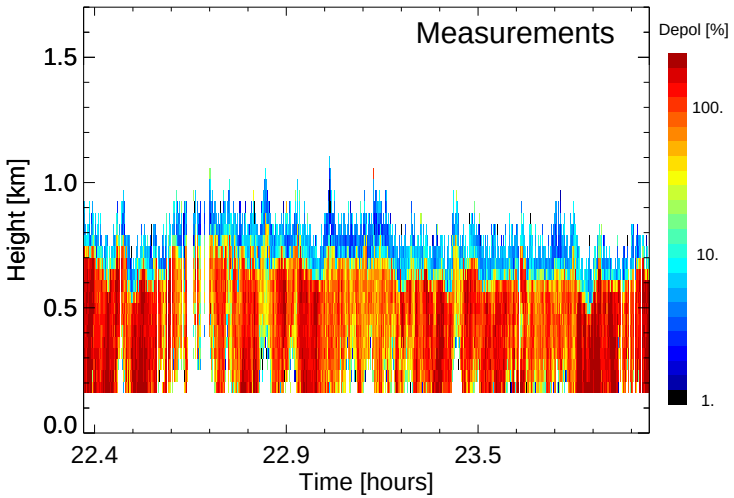

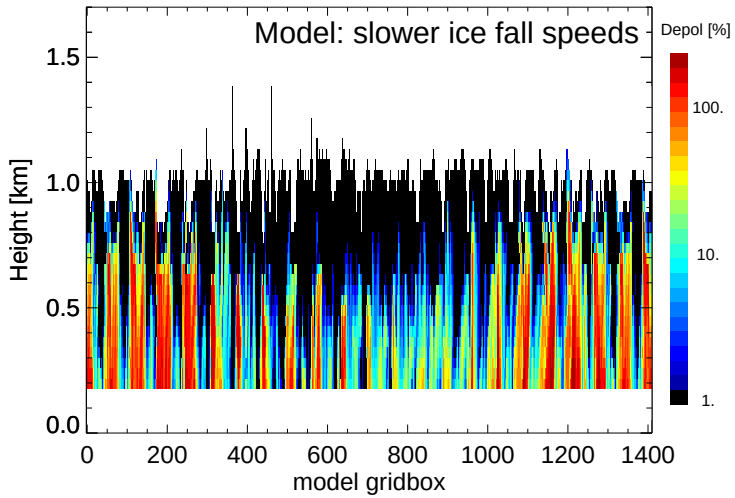

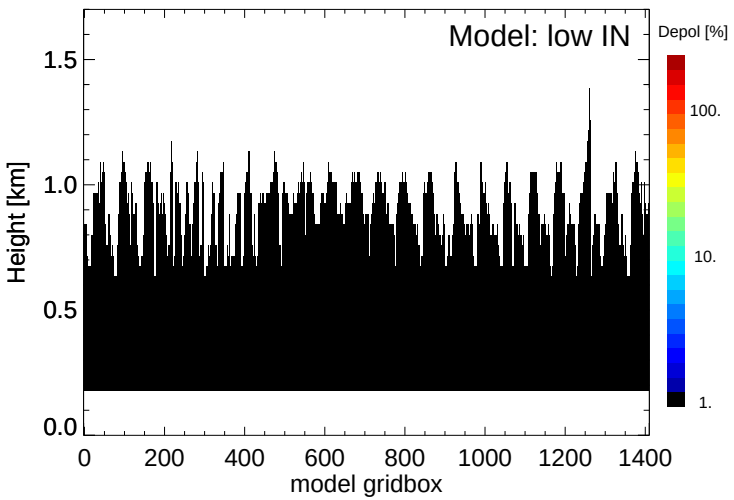

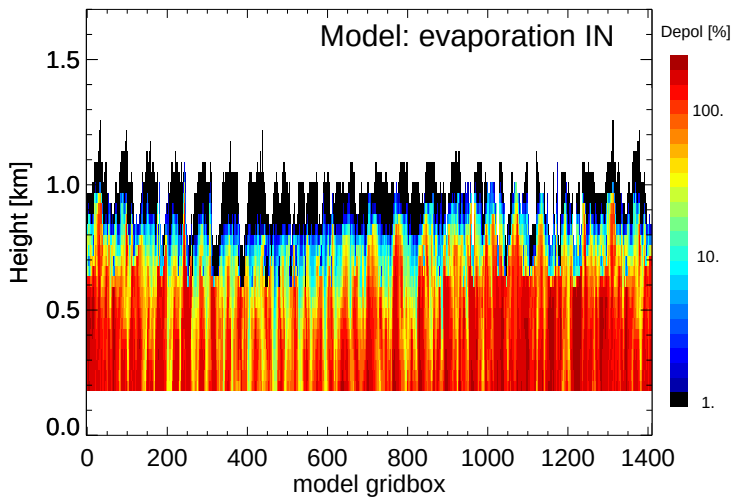

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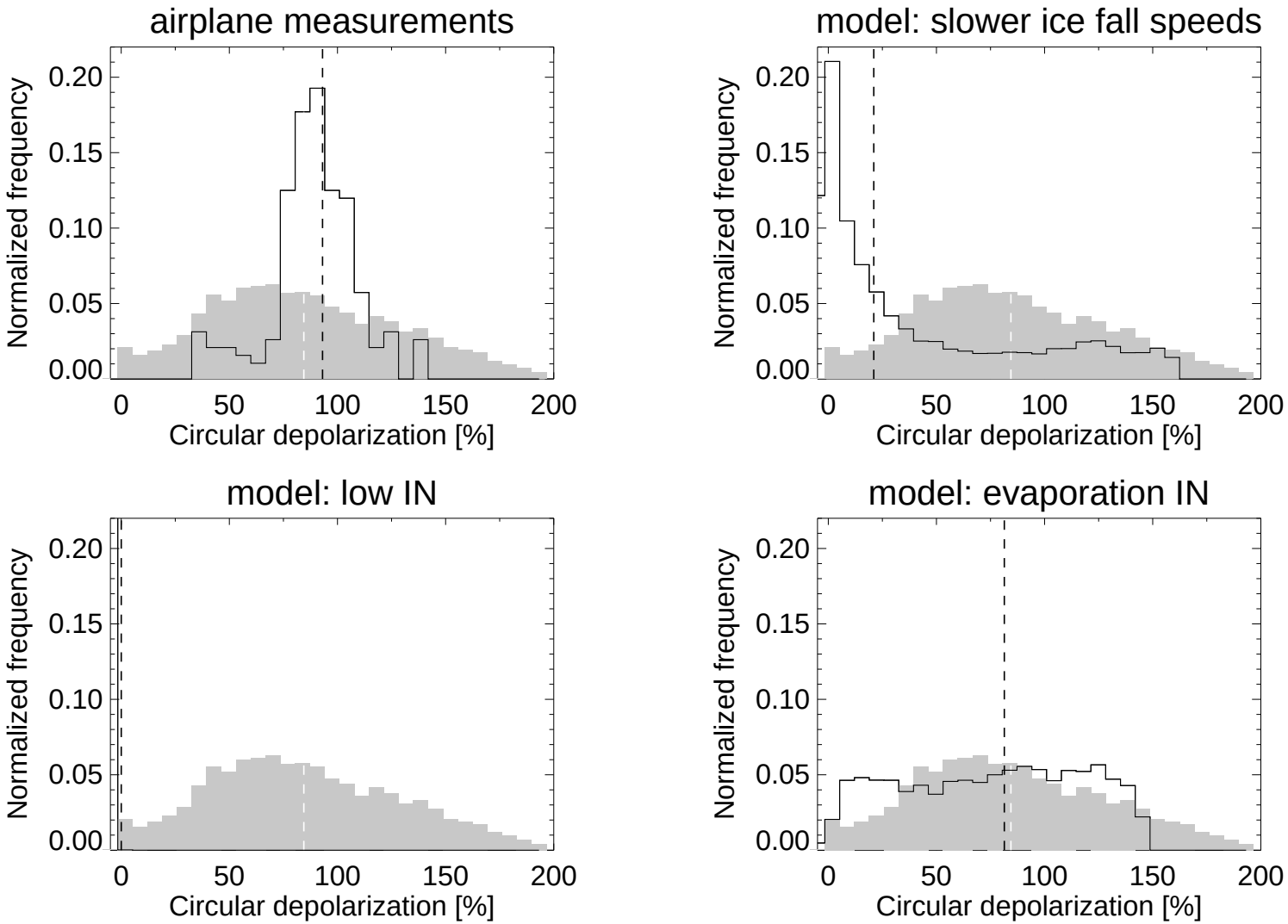

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- future
  - GCMs more like CRMs
  - integrated view of aerosols, clouds, precipitation
  - focus on regional-scale climate and precipitation
  - field-constrained CRM results for mission design